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ABSTRACT: The U.S. Information Technology (IT) industry is both a specific industry and a foundational element for all other major industries. While the industry is strong and can support current National Security Strategy (NSS) requirements, the U.S. must address upcoming challenges to continue enabling and protecting our current and future strategic capabilities. By building and promoting relationships among government, industry and academia, the U.S. government (USG) can overcome the challenges of maintaining a strong IT workforce, protecting critical infrastructures and technologies, managing our intellectual property rights, and transforming our industrial-based military to continue leading the world in innovation and technological superiority.

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Domestic

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Microsoft Technology Center, Reston, VA
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Verizon Communications, Washington, DC
Vonage
Oracle Corporation, Redwood Shores, CA
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Apple Computer, Cupertino, CA
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Brocade Communications Systems, Inc., San Jose, CA
Silicon Graphics Inc., Mountain View, CA

International

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American Chamber of Commerce in Thailand, ICT Committee, Bangkok, Thailand
National Science and Technology Development Agency, Bangkok, Thailand
Mustang Technologies Co., Ltd., Bangkok, Thailand
Software Park Thailand, Bangkok, Thailand
Thailand Science Park, Bangkok, Thailand
National Electronics and Computer Technology Center, Bangkok, Thailand
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INTRODUCTION: Information Technology (IT) is a dynamic, fast-paced and rapidly changing industry. Not only is IT a separate and distinct industry, it also supports every other major industry. Over the last 20 years, major U.S. industries have integrated IT into their operations to realize significant efficiencies. In fact, many believe that IT has been a major contributor to the gains in productivity that enabled the U.S. economy's strong growth since the mid-1990s and supported our unparalleled military capability. According to the Bureau of Economic Analysis (2006), information and communications technology producing industries experienced double-digit growth of 12 percent in 2005, down slightly from 13 percent in 2004. Despite comprising just 4 percent of GDP in 2005, these industries accounted for almost 13 percent of real GDP growth. IT has fed significant growth internationally as well. A recent International Telecommunications Union study found that 27 percent of GDP growth among the G7 leading industrial nations during 1995-2003 was a function of IT investments (Dell, 2006).

Over the last three months, the IT industry study seminar has combined extensive research, comparative market analysis, and discussions with industry associations, private companies, government officials, and domestic and international leaders to assess the health of the IT industry and determine its ability to support the U.S. national security objectives. Through these methods, the seminar built this study highlighting the industry's major themes and issues. Due to the expansiveness of this industry, we first define the industry to set the bounds for our study. Next, the seminar examines the current economic conditions and outlines key trends that public, private, academia and government organizations must evaluate and embrace or face the risk of failure. The final section addresses the industry's myriad of challenges, ranging from intellectual property rights to maintaining our technological advantage in a global and increasingly competitive economy, and evaluates the health of different market segments to determine whether market failures warrant government involvement and to assess the industry's ability to support the current and future national security landscape.

In the end, the seminar determined that the IT industry is in good health and well positioned internationally, due in part to high demand from the government, including the Department of Defense, corporate America, and international business transformation efforts. Nonetheless, the U.S. industry's continued prosperity would benefit from thoughtfully developed and monitored legislation coupled with government, industry, and academia innovation and collaboration to ensure U.S. success and IT world leader status.

THE INDUSTRY DEFINED: Defining the IT industry is less than straight forward. The first challenge derives from IT's standing as an integral component of all major industries. The line between the actual IT industry and IT within other industries is blurred at best and compounded by the fact that many non-IT companies are in fact major producers of IT. The second challenge is defining the segments comprising the industry. The accelerating data and technology convergences have significantly complicated the divisions that used to distinguish IT segments. Although the economic census data is updated every five years and the various North American Industry Classification System (NAICS) codes are updated as required, this market changes so rapidly that the latest 2002 NAICS codes with respect to IT already appear to be outdated and should be revised again in the next Census. To evaluate this industry, we used the Department of Commerce (2002) as a baseline to define IT as those industries that produce, procure, process, or transmit information goods and services. Due to the expansiveness of this definition, we further

refined our study to the following areas and have identified representative companies (in parentheses) we used as proxies for the segments our seminar studied:

A. Telecommunications (Verizon): These firms provide the means through which content and/or data is transmitted between two or more points (i.e. customer to businesses). Mediums include, but are not limited to, wireline, wireless, cable, and powerline.

B. Hardware and Networking (Nortel, Cisco, Apple): These firms manufacture and/or assemble electronic and mechanical equipment. This includes, but is not limited to, mainframes, routers, switches, hubs, workstations, laptops, personal computers, servers and other mobile computer equipment. Computer manufacturing includes the assembly or integration of processors, coprocessors, memory, storage, etc. into a user-programmable final product.

C. Software (Apple, Oracle): These firms produce the coded instructions (programs) that direct computers to perform functions, including, but not limited to, operating systems, databases, e-commerce, and specific applications (i.e. word processing, financial tools, etc.). Software can be divided into pre-packaged and application-specific development.

D. Services (Oracle): These firms provide overarching service and support mechanisms for the industry. This includes, but is not limited to, systems integration, call center operations, product support, information security services, and commercial services.

CURRENT CONDITIONS: IT is a dynamic industry, and a quick review of recent developments will provide increased understanding to support the industry study reviews. Soon after the fall of the Berlin Wall and the Soviet Union's break up, the IT industry soared. While major corporations searched for the latest IT-enabled applications to improve efficiency and boost effectiveness, thereby increasing profits, venture capitalists searched for the next new IT investment opportunity. The late 1990s saw an additional flurry of investment aimed at forestalling Y2K difficulties. While the Y2K doomsday results never occurred, this investment was key to NYC's infrastructure withstanding the 9/11 terrorist attacks and enabling the financial institutions to continue with minimal interruption. All in all, this overinvestment was considerable, yielding funding for often immature technologies and overcapacity, and IT company stock prices rose with "irrational exuberance."

This pattern continued until early 2000, when the dot com bubble burst: within 18 months hundreds of IT companies had declared bankruptcy. Telecommunications equipment, transmission, and application providers were hit hardest. The significant drop in demand for applications engineers and excess transmission capacity created a new challenge for the IT industry. On the one hand, the supply of experienced engineers and IT technicians exceeded demand in the U.S. On the other, outsourcing, enabled by now abundant transmissions means, became more attractive as a result of cheaper labor and long-term costs.

Very few companies were unaffected by the bursting of the dot com bubble. Stock prices of many IT companies are still at only fractions of their 2000 highs. The industry is consolidating at a rapid pace, and companies recognize the need to deliver economies of scale (lower product, overhead, branding, legislative, and marketing costs). Executives are more

cognizant of the potential risk of depending on offshore companies for critical tasks, restructuring is reducing costs, and the public is expressing concerns about the transfer American high tech jobs to lower cost competitors and the resulting loss of expertise within U.S. firms. To gain a more rounded picture of the IT industry, the seminar studied the following five market segments (each with a synopsis of findings):

A. Telecommunications: The telecom industry today can best be described as "in a state of continuous technological and economic flux" (Plunkett, 2005), and it is one of the most competitive industries in the world (Mergent, 2005). The industry today is defined by the following (1) hardest hit companies in the tech stock collapse in 2000/2001 (2) significant mergers, consolidations and financial restructuring (3) increased globalized competition (4) deregulation and privatization, and (5) rapid technology advances (Plunkett).

The telecommunications industry has gone from a natural monopoly to a monopolistic competitive market where companies are now challenged and even threatened by new competitors because of lower entry barriers and bold technological advances in transmission speeds, content quality, available offerings, etc. While there is still a thread of near-monopoly power with local phone and cable companies in their localities, their market power is decreasing. Current legislation stove-pipes companies based on transmission mediums, but is outdated because of technological advances. These advances have fueled the call for legislative action to update the 1996 Telecommunications Act. Unfortunately, some companies are using this as an opportunity to lobby for anticipatory legislation on network neutrality and other high-profile industry issues.

Globally, telecommunications revenues totaled approximately $1.4 trillion in 2004. The U.S has been, and will continue to be, the largest global market with 30 percent of the total (Verizon, 2004). Our domestic market continues to grow with spending climbing 7.9 percent from $720.5 billion in 2003 to $784.5 billion in 2004 (Gallagher, 2006) and growth of nearly 10 percent annually anticipated through 2008 (TIA, 2005). Wireless revenue is up from $71 billion in 2000 to an estimated $140 billion in 2005. In contrast, wireline revenue dropped from $292 billion in 2000 to an estimated $198 billion in 2005. With the exception of T-Mobile, a subsidiary of Deutsche Telekom, U.S. telecom providers are domestically owned and well-positioned to support future transmission requirements.

B. Networking: The enterprise networking segment is healthy and growing, with most operating margins averaging 20 percent in 2005 (Reuters Business, n.d.). Companies such as Nortel, Siemans, Cisco, Alcatel, and Avaya are expanding into end-to-end products and services, providing enterprise-wide network solutions to businesses and governments. Open and vigorous competition, global market expansion, new innovative technology and few regulatory barriers to market (entry or exit) have led to healthy competition and a wide array of new products and services that are quickly introduced, marketed and sold; to the apparent satisfaction of consumers.

While the segment is competitive and absent signs of major market failure, there is government involvement and regulation. Such regulation has positive and negative effects on the operations in the segment. On the positive side, government intervention is liberalizing

international trade in IT goods and services, increasing the prospects of the U.S.-based industry overseas, and government support for basic research and science and engineering education is largely positive. On the negative side, some regulation increases the costs of doing business. On the whole, however, government regulation of the sector appears light handed, leaving this segment of the industry healthy and well able to support the U.S. national security interests.

C. Manufacturing: The personal computer manufacturing industry has also changed considerably over the last few years. HP and Dell rule the computer hardware market in the U.S., HP through retail channels and Dell using its pioneering direct sales model. With a focus on aesthetics and a user-friendly operating system, Apple has achieved a niche with its "user experience" focus and huge success of its iPod. Other U.S. companies include Packard Bell, Gateway and Lenovo, which purchased IBM's PC manufacturing division in 2004. However, these companies are slowly losing market share and must re-evaluate their positions in a field dominated by HP and Dell. Additionally, the USG may rescind recent orders of Lenovo computers intended to manage classified information (Reuters, 2006).

Several leading companies, including Dell, now handle the majority of their production in countries with lower-cost labor, such as China, thereby reducing production costs and helping margins against the increasing threat of commoditization (Reuters, 2006). Just as important, this provides considerable benefit to consumers, both individuals and businesses. Additionally, import competition has wiped out major parts of the domestic consumer electronics industry, and the ultimate effect of this competition depends on market developments. Notwithstanding the disappearance of large segments of domestic production, consumers and the country benefited considerably from the decline in prices brought about by the globalization of production and competition. The U.S. industry is likely to encounter continued strong competition from imports originating throughout Asia and Europe (http://www.bls.gov, 2006).

The computer and networking market continues to expand globally, fueled by growth in enterprise computing and proliferation of mobile communications devices. In this competitive and highly concentrated industry, firms face intense price competition and growing shareholder demands to fulfill earnings expectations. In turn, these pressures drive strategies for faster time to market, supply chain optimization and consolidation (Computers and Networking, 2006).

The five-year outlook for IT services spending in the manufacturing sector puts total spending at $455.7 billion by 2009 (Gartner, 2006). The growth of digital technology, artificial intelligence and nanotechnology, as well as expansion of the Internet and growing demand for global information networking, will continue to create new opportunities in the public, private, and military sectors (http://www.bls.gov, 2006).

D. Hardware: The hardware industry is very healthy, and the U.S. leads the sector with the most dynamic companies in the world. The devices used to connect users to the Internet include routers, switches, modems, and advanced technologies such as optical switches.

The Internet started some 20 years ago as a means to send small packets of information via email. Since that time, there has been an explosion of computers and devices connecting to the Internet. It has been estimated that by 2010 as many as 14 billion devices will be connected

to the Internet (Cisco, 2006). These devices will offer many services including videos, games, Internet telephones, video teleconferencing, etc.

For this industry segment, we used Cisco Systems as our proxy. They are the worldwide leader in networking technologies with approximately 70 percent of the global market. For China's latest network upgrade, "CN2," which began in mid-2004, two U.S. companies, Cisco Systems and Juniper Networks, were granted four of the six contracts. Cisco Systems currently has 60 percent of the Chinese market for routers and switches and earns $500 million annually in China (Bambauer, 2006).

E. Software/Services: The software industry sector is healthy overall with strong operating margins, high revenue growth, low debt levels and high liquidity. Over the last five years, the market has demonstrated consistently strong growth patterns, buoyed by strong PC sales, which pushed the market to almost $73 billion at the end of 2004, with annual growth of 4 percent forecast through 2008 (Reuters, 2006). Over the past several years, trends are positive, with sales up on average 10 percent and total revenues up 10-20 percent for the top companies. Operating margins are averaging 25 percent for the software and services sector, well above the S&P 500 average of 18 percent. Although investor confidence is shaky due to the concern of the larger companies efficiently integrating their recent corporate acquisitions, the stock prices have remained essentially steady for the major companies (Reuters, 2006).

While this industry has thousands of companies, large corporations such as Microsoft, Oracle, Germany's SAP, Computer Associates, and IBM dominate the market and consolidation is continuing. Nevertheless, niche markets are well-utilized by smaller companies, both public and privately owned. This segment exhibits strong competition, albeit largely oligopolistic, which has driven rising research and development (R&D) spending as companies increasingly seek to differentiate their products within the highly competitive marketplace. The top five companies spend 12-15 percent of total revenues on R&D (DataMonitor, 2005). The size of the sector, the large number of smaller competitive suppliers, and the plethora of substitutes serve to mitigate exercise of significant market power by the larger corporations.

U.S. software and services firms are competitive internationally as evidenced by the fact that eight of the top ten companies are U.S. owned (Reuters, 2006). While many companies are exploiting offshoring, most of the technical software design and engineering, sophisticated R&D and project management continues to be done domestically. U.S. companies will continue to exploit software programming talent overseas to handle less sophisticated software coding tasks.

Government involvement in this sector, appropriate for the most part, has been primarily focused on Microsoft and its alleged anti-competitive behavior. The USG does subsidize the industry somewhat, primarily through R&D tax incentives. However, the competitive nature of the sector forces companies to aggressively pursue product improvement anyway; thus the need for government subsidies is questionable.

OUTLOOK AND TRENDS: The U.S. continues to lead the world in technological advances and innovation. While our discussions and research did not indicate a significant challenge to this status over the next decade, the U.S. cannot afford complacency. Over the next few years significant technological change is certain, and the U.S. must remain at the forefront. Just as

important as remaining the innovation superpower, we must improve our ability to apply these technologies into daily operations to improve productivity and maintain military superiority.

A. Overall Economic Forecast: According to the most recent data from the International Monetary Fund (IMF) (2006), the global economy grew at a healthy pace during the past two years (5.3 percent in 2004 and 4.8 percent in 2005), and the IMF projects comparable growth in 2006 and 2007 (4.9 and 4.7 percent, respectively). Growth in the U.S. and China, in particular, is important for IT because they are both drivers of world economic growth and huge producers and consumers of IT products and services.

Data from the Organization for Economic Cooperation and Development (OECD) shows that IT services in the U.S. contributed 11.5 percent of total value added by business services in 2001. IT manufacturing was similarly important, providing 10.9 percent of manufacturing value added in the same year, meaning IT accounted for well over 10 percent of U.S. industry value added in 2001. In 2005, exports of computer and telecommunications equipment and semiconductors accounted for 8.5 percent of all U.S. exports, while imports of these same IT products accounted for 10.8 percent of all U.S. merchandise imports. While China has yet to match the U.S. as a producer or consumer of IT services, it did pass the U.S. as an exporter of IT products in 2004 (OECD, 2005). As China's own economy moves up the technology ladder, IT services can be expected to become increasingly important. As the IMF notes (2006, p. 117), China's exports are increasingly "high tech" and high skill; IT services are bound to follow.

Prospects for continued growth in the IT industries world wide over the mid-term appear favorable. Penetration rates for computers and for Internet access are high – above 60 percent – in most industrialized economies, but significant expansion is still expected (OECD, 2006, p. 141). Additionally, IT services have generally increased their relative share in the overall industry in recent years and of business services value added. This reflects the continuing shift towards a services economy (as more manufacturing moves offshore), as well as the growing importance of telecommunication and computer (especially software) services. These two facts point to continued strong economic growth in the IT industry over the next few years. As China, India, and Southeast Asian emerging markets continue their upward trends, IT support and services should increase significantly. Low penetration rates and increasing demand due to technological advances, and enabled by strong economic growth, should allow U.S. IT firms to benefit over the mid to long-term.

B. Telecommunications: Recent significant change in the telecommunications market is expected to continue. The convergence of voice, video and data has increased competition in each of these market segments. Traditional (cable, telephone) and now even non-traditional (utility) firms are entering the high-speed internet access market through broadband, wideband, ultra wideband, etc. technologies. Development of "last mile" technology has also produced Internet access substitutes allowing multiple service providers to reach individual residences and businesses directly. Internet applications such as Voice over Internet Protocol (VoIP) are using IT to challenge traditional wireline and possibly wireless telephone providers. The telecom world is rapidly shifting from wireline to wireless, narrowband to broadband, voice-centric to multi-media, circuit-switched to packetized, copper to optical infrastructure, proprietary to open architecture, and traditional to market-based regulation (McKeehan, 2006).

The distinction between voice, data, and video, which traditionally could be made based on the transmission network required for each, is essentially no longer applicable. Yet government regulation continues with both feet planted firmly in the past, employing a framework and bias that have not kept pace with changes in the industry. The result is different regulations for directly competing services.

As mobile requirements increase, one of the chief emerging technologies focuses on wireless capabilities. Third generation (3G) wireless systems enhanced standard voice and paging services with interactive multimedia, including teleconferencing and internet access, but providing broadband services will require the fourth generation of wireless systems (4G or 4G Wireless Standard). Although 3G is still being implemented, 4G is right on its heels, and many wireless users are looking to leapfrog directly to 4G. While there are a few differences, the biggest is the data rate. 3G can provide speeds to 2 Mbps while 4G reaches 20Mbps or more.

Analysts project that 4G cellular systems will account for 14 percent of worldwide mobile wireless data revenues by 2007, with 50 million subscribers by the end of that year, and the spend for 4G infrastructure is projected to reach $5.3 billon in 2007. Despite these threats, 3G should also grow. In 2007, 3G is expected to reach 90 million users (mainly in Japan and Europe). Yet prospects for 3G are uncertain, as 4G is gaining momentum faster than predicted (Cullen, 2002).

C. Hardware: Recent extraordinary advances in computing power have been accompanied by equally impressive advances in hardware. Continued U.S. development and application of new hardware technologies is vital to sustaining economic progress, technological competitiveness and ultimately U.S. national security. Specifically, significant advances have been made and will continue in the following areas:

Data Storage: Data storage refers to both the devices and the techniques of accumulating and managing data. An increase in regulatory (Sarbanes-Oxley Act (SOX) for example) and operational data storage requirements, coupled with an exponential decrease in data storage costs, is driving innovation in storage systems, and users are moving towards a tiered storage infrastructure (Zaffos, et al., 2005). According to a 2003 study by the Enterprise Storage Group, the global volume of records stored in compliance with SOX shows a compounded annual growth rate of 64 percent from 2003 to 2006 (Warmenhoven, 2005). In addition to businesses, demand for personal storage has skyrocketed with the proliferation of digital photography, videography, and music (Plunkett Research, 2006).

Alternative storage technology research is ongoing, but the hard disk drive (HDD) remains the mass storage product of choice. Through 2009, and likely though 2015, current HDD technology will prevail in all legacy PC and high-end storage markets. NAND flash is the most-recent challenger to HDDs, but this technology is still immature. The industry delivered 29.9 million HDDs in 1990 and increased deliveries to nearly 375 million in 2005. Gartner Dataquest conservatively forecasts shipment of more than 650 million HDDs in 2010 (Masaki, et al., 2005). Purchased terabytes of storage are growing on average across the industry at 60-70 percent every year, resulting in data storage continuing to be a major portion of IT spending.

Widespread use of virtualized storage across networks as a shared resource for servers will continue, and reduced cost, improved availability and shorter recovery times will be enabled by technologies such as tiered storage, data and information life cycle management, archiving and space-saving snapshots (Passmore and Adams, 2005).

Supercomputing: Supercomputers direct their power into executing a few programs (normally very specialized applications that require immense numbers of mathematical calculations) as fast as possible. Supercomputers are critical to basic and applied advanced research, cryptography and encryption sustainability.

The fastest supercomputer in the world is IBM's Blue Gene/L machine being built with the Department of Energy's NNSA/Lawrence Livermore National Laboratory (Top500 Supercomputer Sites, 2006). The Blue Gene project aims to explore frontiers in computer architecture, in the software required to program and control massively parallel systems and in the use of computation to advance the understanding of important biological processes such as protein folding. It has achieved maximal LINPACK performance of 280.6 Teraflops (a trillion floating point operations per second) with a theoretical peak performance speed of 360 Teraflops. IBM and its collaborators are exploring a growing list of applications including hydrodynamics, quantum chemistry, molecular dynamics, climate modeling and financial modeling (Blue Gene, 2006a). Silicon Graphics hopes to launch a machine that will run one quadrillion calculations per second (petaflop) by 2009, unless their recent bankruptcy declaration derails these plans (Plunkett Research, 2006).

Grid computing is revolutionizing supercomputing platforms. Grids unleash latent power otherwise unused, facilitating huge gains in power, speed and collaboration while radically accelerating computer-intensive processes (IBM Grid Computing, 2006).

As an even higher goal, researchers are investigating the concept of ***quantum computers,*** which store and process information by exploiting the laws of quantum physics. Classically, a computer processes information represented in binary units. In quantum computing, the unit is a quantum bit or qubit. A qubit can exist as a binary unit, but also in a simultaneous state of both 0s or 1s, which increases the number of states that can be processed by a computer. The quantum computer would gain enormous processing power by performing tasks using all possible permutations simultaneously. In layman's terms, the leap in computing power would be greater than a leap from the abacus to a supercomputer. Current centers of research in quantum computing include MIT, IBM, Oxford University, and the Los Alamos National Laboratory (Whatis.com, 2006). Although progress has been made, many experts don't see practical results in this area for many years, if not decades.

Efficient Servers (Power): The server market continues to change significantly. There are approximately nine million servers in data centers across the U.S. (Wisegeek, 2006). Data center electricity costs to power and cool equipment are growing quickly as companies deploy increasing numbers of servers. Electricity costs in data centers are already in the annual range of $3.3 billion, and the number of servers in the U.S. may jump 50 percent over the next four years. As companies build new facilities, they are more focused on cost per watt than the cost per square foot of space. Data centers already average one serious power outage per year

and 20 percent of centers are running at over 80 percent of their power capacity (Dunn, 2006). Server sales will continue growing about 14 percent through 2009, increasing the problems of data center real estate, server utilization and cooling and power costs (Burt, 2006).

On the immediate horizon are virtual servers, also known as virtual hosts, referring to the practice of serving more than one address/site on a single host machine. The fact that these multiple sites are being served by the same physical machine is transparent to the end user (ProFTPD and Virtual Servers, 2006).

D. Software: While software improvements have been significant and the industry is highly competitive, IPv6, Open Source and Open Standards are three key issues/trends that will enhance our competitive advantage.

IPv6: The explosion of network-dependent businesses and consumers has highlighted a shortfall in Internet addressing infrastructure. The current Internet Protocol Version 4 (IPv4) uses a 32-bit addressing scheme to manage addresses; unfortunately, assigned network addresses are limited to 4.3 billion, and we may hit this mark as early as 2010 (Hain, 2005). IPv6, on the other hand, can provide 3.4×10^{38} unique addresses and allow almost any electronic device to have its own address.

Along with more address spaces, IPv6 provides improved mobility by allowing users to move seamlessly from network to network while keeping the same unique IP address. The ability of IPv6 to allow devices to attach dynamically to networks is essential for the success of several evolving mobile service features in personal digital assistants, laptop computers and automobiles (Fritsche and Heissenhuber, 2000).

Most IT professionals agree that IPv6 is a significant and difficult upgrade in Internet technology. Given the magnitude of the effort to migrate all global users, both IPv4 and IPv6 protocols will coexist for an extended period of time. Because of this time lag among sectors and even countries, an organizational IPv6 transition strategy is essential to mitigate transition costs and risks (Bound and Latif, 2004). To assist, the Internet Engineering Task Force has focused its protocol design efforts on providing network administrators the flexibility to incrementally upgrade networks.

Open Source: Open source software is software whose source code can be viewed, modified and redistributed at marginal cost (Frost, 2005). Well known examples include Linux, Apache and MySQL. Open source software development is based on decentralized collaboration where individuals voluntarily produce enhancements and features to software projects of interest. Open Source Development Communities are non-profit providers of software distributed on the Internet for all to use.

Advocates of open source software emphasize the benefits of a broad support community, increased flexibility and more control over mission critical technologies (Gruman, 2006). The broad support provides reassurance that support will continue, as opposed to proprietary software depending on an individual contributor who may go out of business or change market direction. However, successful use of open source software increases the

required level of in-house IT staff knowledge and creativity, and time is required to stay abreast of developments in the open source community.

With several large software vendors such as Sun, Oracle and IBM investing in open source projects, business models for software are beginning to shift from traditional packaged licenses to an open source subscription-support type model (McAllister, 2006). The decision for a customer to move to an open source solution depends on an engaged and active developer community, which will be enhanced by the participation of these industry mainstays. The open source approach is an increasingly robust alternative and continues to make gains in proprietary software markets.

Open Standards: The recent dramatic rise in information flow as the result of globalization, low cost technology and the Internet is driving an increased emphasis on openness and interoperability to gain efficiencies and flexibility among diverse IT systems (Berkman Center, 2005). Open standards ensure interoperability by defining internal and/or external interfaces that represent common agreements which enable communications open to all.

Open standards are developed by standards-setting organizations like the Internet Engineering Task Force (IETF), the American National Standards Institute (ANSI), and the International Organization for Standardization (ISO). These organizations ensure that newly developed open standards are transparent and not built on closed proprietary standards.

Open standards have almost reached a critical mass in the mainstream world market, and their impact is becoming noticeable. They have become the backbone of a service-based approach by ensuring technology neutrality and eliminating the need for custom coding to link service components. Companies such as IBM, SAP, Sun, Intel and Hewlett-Packard are committed to using open software as a core part of their business models and investing to enhance its capabilities. (Murch, 2004)

The U.S. government's role in the domestic and international IT standards-setting process is to provide feedback as an important user and to endorse individual open standards. The future is moving to more open and unified systems, especially in military operations that will increasingly include allied and coalition partners.

E. Services: The increasing pervasiveness and reliance on IT by businesses, government and the individual consumer has significantly increased the challenge in providing world-class service at affordable prices. The large number of unique systems in operation complicate the challenge. The DoD alone has over 6,200 unique systems; the problem in industry may be 100 times larger (Yelton, 2006)**.** Additional factors include the unintended consequences of non-standard data fields, a lack of interoperability, non-supported applications and massive inefficiencies. In contrast to this growing U.S. problem, China, with very few legacy systems, has been able to create a modern IT infrastructure and gain significant productivity advantages.

To address these challenges, industry is adopting consolidation and central management through Core Enterprise Services. Companies are offering this service through websites, which seamlessly interface a variety of applications over a variety of platforms and software.

Organizations are embracing this centralized and controlled environment as it eliminates or significantly reduces equipment requirements, stovepipes, security vulnerabilities, viruses and potential theft of company proprietary data.

Another development gaining momentum is Software as a Service (SaaS), which delivers software based on network access. It outsources the management and maintenance of an enterprise's software to a third party with user access to applications over a network. Delivery of software services has been implemented in two forms. The first is where a customer purchases and brings to a service provider a copy of the software, or the hosting company offers widely available software titles for use by customers. The software offered in this case is typically off-the-shelf (such as Microsoft Office) made available across the web to a customer who pays a monthly fee for access. The second SaaS business model offers what is often called software on-demand, where a company offers software specifically built for one-to-many hosting. This means that one copy of the software is installed for use by many companies who access the software across the web. The software being delivered by this second method is tailored for efficient delivery of the function requested by the user. In both methods of delivery, the service provider is responsible for configuration management and maintenance of the software.

At the core of the SaaS function is another enabling technology called Service Oriented Architecture (SOA). Fundamentally, SOA is a loosely coupled system of applications, accessed via the network with common interfaces to be invoked by the user. It has the potential to become wide spread as it may provide significant savings in IT infrastructure for the user. Reuse of software and only "buying" the application needed are among the key benefits. But, overall system integration and interoperability of data and applications are hurdles that need to be overcome. Interface standards will be critical to the successful implementation of SOA.

While private and public corporations started the consolidation and central management themes, the Department of Defense is also migrating toward this framework with the net-centricity mantra, the cornerstone of Defense transformation--as emphasized in both the 2004 National Military Strategy and the 2005 Quadrennial Defense Review (QDR). The IT industry plays a central role in the success of DoD's net-centric vision, and there are numerous commercial opportunities for all sectors of the industry.

At the heart of net-centric operations are the Global Information Grid (GIG) and Net-Centric Enterprise Services (NCES), or the joint integrated network, which the QDR identified as the single most significant joint enabler. The GIG and NCES combined are a globally interconnected, end-to-end set of information capabilities, associated processes, and personnel for collecting, processing, storing, disseminating, and managing information on demand to joint warfighters, policy makers, and support personnel. The Network includes all owned and leased communications and computing systems and services, software (including applications), data, security services and other associated services necessary to achieve information superiority (HQDA, 2006). It will eventually link defense users to interagency elements and multinational partners. The Network is intended to enable leaders to command and control forces, sustain the force with minimal forward presence and achieve broad politico-military objectives. The Network will be a single, integrated entity – a joint, collaborative environment, which replaces

the myriad of stove-piped networks found within the services, combatant commands and various government agencies today (US Army Futures Center, 2005).

The GIG will continually evolve and grow as policies, technologies and requirements mature and services/agencies integrate their systems into the GIG/NCES. For example, DoD is overhauling its communications network (optical network foundation), to include terrestrial infrastructure, satellite systems and tactical radio systems. In all cases, using commercially available products is critical to GIG development (Richard and Roth, 2005).

To succeed in the future, this industry and the DoD will continue consolidating (gaining efficiencies of operation through adopting best practices and economies of scale) and integrating many systems. The ability to effectively utilize the Internet with Core Enterprise Services will be a defining competitive advantage in the future.

F. Data Convergence: In the past, the distinction between voice, data and video would traditionally be made based on the transmission network required. This is no longer the case and the Internet has fundamentally changed the way the world communicates. Internet Protocol, or IP, now allows voice, video and data to be transmitted over a single network that can be copper, coaxial cable, fiber-optic or wireless. Rapidly advancing technology, including improved wireless and broadband services, is fueling the growth of digital convergence which now allows a single device to perform many functions. The result will be an increasingly digitized and interconnected world where a single portable device can replace many items including keys, credit cards, identification, telephone, camera and TV. Convergence will increasingly allow individuals to seamlessly access and use information. Convergence is also blurring the line between historically distinct industry segments. For example, the line between cable TV and telecommunications has been removed as cable companies now provide telephone and Internet service and telecom companies now provide TV and video services.

G. Nano-technology: This new field studies structures, devices and systems at the atomic or molecular levels less than 100 nanometers in size (A nanometer is one billionth of a meter or about one-thousandth the width of a human hair). Development in this field has been ongoing for 15-years, remains promising and can have a profound impact on nearly all aspects of society, particularly in areas like medicine, manufacturing, energy and IT (Ghadar and Spindler, 2005). Potential benefits include smaller, lighter, more capable products and services at cheaper costs. Case in point, computer hard drive storage capacity has increased over six hundred times since the mid-1950s, while decreasing significantly in size and cost (Stanishevskaya, 2004). It's quite possible that nanotechnology could help increase the availability of food, energy and water appreciably in the future (Glenn and Gordon). On the other hand, nanotechnology risks aren't fully understood, models are inadequate and regulation is sub-standard. Risks may be less significant in IT, but the ability of a nano-particle to penetrate the human skin is critical in bio-technology and other fields.

In 2001, the U.S. started the National Nanotechnology Initiative to accelerate the pace of nanotechnology development (National Institute of Standards and Technology [NIST], 2006). In addition, the country stood up the Center for Nanoscale Science and Technology in 2006 to facilitate the development of nanotechnology into practical, market-ready products and solutions.

The center brings together the collaborative knowledge and capabilities of NIST, industry, academia and other government entities in nanotechnology (NIST). President Bush requested an additional $20 million in the fiscal year 2007 budget to accelerate the expansion of the Center's capabilities. Since 2001, the U.S. has invested over $6.5 billion in nanotechnology research and development (National Nanotechnology Initiative [NNI], 2006). To take nanotechnology to the next level and beyond, the U.S. needs to continue investing appropriately in basic science research, as well as R&D, and to leverage public and private resources.

CHALLENGES AND GOVERNMENT RESPONSE: While the IT industry has recovered considerably since the dot com bubble burst, a return to the inflated pre-burst glory years is unlikely. However, economic data show an upward trend in IT, and companies are strategically positioning themselves to meet increasing demand. While the outlook is improving, the market is imperfect, and there are failures. To ensure the right information technologies are available to enable and support our national security, the USG must stay engaged in and with the industry. The key is to determine when and where to intercede to help counteract market failures, guarantee national security enabling and limit unintended consequences. The following sections address important, but certainly not all, challenges the USG and IT industry firms face in ensuring the U.S. maintains its comparative technological and security advantage. Overall, ***our seminar has determined that the current IT market failures do require continuing, but limited USG involvement.***

A. IT Regulation: If market forces and primarily self-regulation hold sway, Internet innovation will continue its technological advance. If heavily regulated, this "network of networks," and the "public good," may fall prey to political forces and bureaucratic burden. While there is a need for some regulation in the U.S. and elsewhere, IT companies already face a huge number of regulatory requirements, and lawmakers continue to address areas such as: telecommunications, spam, piracy, privacy, net security, freedom of speech, spyware, malware, identity theft, federal campaign laws, broadband access, net neutrality, costs of access, cyber crime, pornography, gambling, domain name management and other issues. Compliance with these requirements, while well-intentioned, is increasingly difficult. For example, Sarbanes-Oxley Act financial reporting and data/document retention requirements have levied significant costs on businesses, which small and medium enterprises are often unprepared to bear.

Recommendations: Price competition, increasing service options, expanding coverage and technological advances reflect market success that lends itself to less, not more, government involvement. Initially, Congress must revamp the 1996 Telecommunications Act to support the current converged industry. The first question asked must be, "What is really needed," and developing an "exit strategy" from most regulatory guidance isn't a bad answer. The next step is to significantly reduce the regulatory burden. The goal is to limit anticipatory legislation, while ensuring equal access to both domestic and international markets, available public service support (i.e. law enforcement, emergency services, etc.) and improved national security capabilities. The USG must remain vigilant on the international stage to vigorously combat attempts to regulate the Internet.

B. SECURITY: Former Director of Central Intelligence George Tenet (2001) remarked that "we have built our future upon a capability that we have not learned how to protect." The

U.S., as most countries, relies heavily on IT to successfully provide capabilities and services within all major industries, sectors and segments. In fact, basic services like power, telecommunications, transportation and financial services are controlled, managed or enabled by computer systems. As the world has globalized, these systems have become "entangled," and entire system integrity is only as good as the weakest link, implying that protecting these systems is critical to our national security and economic prosperity. In fact, we believe that IT security warrants the same national level of attention as the War on Terror receives.

1. Information Assurance: The high availability and penetration of the Internet, coupled with inexpensive cyber-weapons, has led to a significant increase in cyber-attacks (Knapp and Boulton, 2006). Approximately 15 percent of the world's population is connected to the Internet, and this number is expected to grow beyond 50 percent within the next 15 years, placing increased importance on a viable information assurance (IA) plan (Glenn and Gordon, 2006). The number of attacks against information and communication infrastructures rose over 400 percent from the mid-1990s to the early 2000s (Gellman, 2002). According to a survey of 1000 large companies, the number of attacks carried out through the Internet increased by an annual rate of 64 percent (Knapp and Boulton). These attacks are also increasing in sophistication and capabilities (Casey, 2006). For example, attackers are using more advanced intrusion and encryption systems to access networks and disguise their activities. Equally disturbing is the ease of obtaining cyber-weapons. One information system security expert located over 6,000 hacker sites that contained downloadable cyber-weapons (Jones, Kovacich and Luzwick, 2002). The ease and proliferation of cyber attacks, along with increased U.S. reliance on information systems, makes information assurance a top priority for the military, government and corporations.

Recommendations: To improve information assurance, the U.S. must increase public awareness of the risks as highlighted by the Department of Homeland Security (DHS) (2006). The more educated our society becomes, the better protected all will be, leading to significant reductions in identity theft, intrusions, productivity inhibitors and lost capabilities. Secondly, we must enhance the collaboration between the public and private sectors. Too many times, state and local officials haven't been informed of federal IA initiatives (Burkhammer, 2006). DHS must take the lead in developing better tactics, techniques and procedures to enhance collaboration, teamwork and ultimately successful operations. Additionally, they must frequently exercise at all levels of government and law enforcement to assess and improve the health of IA programs. Finally, we must stay ahead of hackers and crackers by improving relationships and investing in new technologies. While many experts agree that we are adequately investing in current and near-term requirements, little to no investment is earmarked for mid- to long-term threats in this area (Vatis, 2001).

2. Critical Infrastructure Protection (CIP): Over 90 percent of U.S. critical infrastructure is publicly owned (CSIL, 2001), and financial, telecommunications, power, energy, transportation and other industries have increased their dependence on IT systems to perhaps an alarming extent. In fact, the management of many systems is now automated through Supervisory Control and Data Acquisition (SCADA) systems. General John Shalikashvili (1996), former Chairman of the Joint Chiefs of Staff, stated "(u)se creates dependence, and dependence creates vulnerability." Unfortunately, protective measures have lagged far behind the increase in operational reliance. As these industries are increasingly becoming "systems of

systems" in this globalized and integrated world, it only takes one vulnerability to impact other critical systems. Unfortunately, the viability of our critical infrastructure can be disrupted through any of its weak links.

Recommendations: Due to our reliance on our critical infrastructure, CIP can't be ignored. The market should drive required change, and there are some positive signs: computer security budgets have increased significantly over the last few years. However, CIP efforts are neither coordinated nor focused, and protection may be inadequate, especially at the seams. The first order of business is to help DHS streamline its organization to ensure the right priority and emphasis on CIP. Secondly, DHS must have Presidential authority to direct, in the interest of national security, instead of "relying on partnerships and building relationships." Their daunting bureaucracy and organizational span has hindered their efforts. After 2½ years, the National Infrastructure Protection Plan is still an interim document. As the framework to "provide a consistent, unifying structure for integrating CIP efforts into a national program" (INIPP, 2005), this document is critical. The USG must also continue fostering relationships to leverage industry and academia expertise. A final area is to review the applicability of existing safety regulations to hold corporations accountable for critical security measures rather than having the USG assume all responsibility. These preventive measures would definitely increase CIP costs, but the alternative is far costlier in both dollars and lives.

C. LABOR AVAILABILITY: Thomas Owen (2006) recently shed light on allegations of inadequate numbers of educated domestic workers, stating that in the next five years, the fastest-growing occupations for college-educated workers will be in the IT field. Overall, the science and engineering (S&E) fields will grow 26 percent faster than other positions by 2012. The trend is compounded by our aging S&E workforce.

Our own education system can produce enough engineers, and the U.S. still has the premier education system at the tertiary level. However, graduates with S&E degrees continue to earn less than those in business and other professions, providing little financial incentive to study S&E. In 2004, American colleges and universities awarded a record 233,492 undergraduate S&E degrees, reports the NSF, up 38 percent from 1990, and computer science degrees have doubled since 1990. Widely publicized figures from China and India perpetuate charges the U.S. is losing its competitiveness. Thus while China and India are graduating 600,000 and 350,000 engineers respectively, the numbers are misleading and include technical degrees that are not equal to U.S. engineering degrees (Samuelson, 2006). However, the number of American students pursuing advanced S&E degrees is down. At the Ph.D. level, for example, 66 percent of electrical engineering graduates are foreign born (SIA, 2006).

In today's immigration reform debate, the focus is on border security and the estimated 11-12 million mostly uneducated, undocumented workers in the U.S (Kirkwood, 2006). Potential high-end immigrants with masters and Ph.D. degrees who would like to stay in the U.S. get little attention. Foreign students and workers can enter the U.S. with non-immigrant visas for students (238,000 issued in 2005), for inter-company transferees (65,000 issued in 2005) and for specialty workers (65,000 issued in 2005, down from 195,000 in 2003 due to a reversion to prior limits) (SIA, 2006). However, all categories limit the time a foreigner can stay in the U.S., and students are officially authorized only one year of work after graduation.

Recommendations: Market forces are driving IT engineering supply at the bachelor's and to a lesser extent master's level. Problems do appear on the horizon at the doctorate and post-doctorate level in light of current immigration rules. The federal government is facing a looming human capital crisis in its S&E workforce due to the unbalanced downsizing that took place during the 1990s. In addition, the federal government has difficulty competing for human capital against the private sector due to pay, time-to-hire, security clearance issues, etc. Effort should be made to attract engineers to work for the USG to mitigate that shortage. DoD is trying to address the gap with the Science, Mathematics and Research for Transformation (SMART) program, which provides scholarships in exchange for a period of employment with DoD (Williams, 2006). The USG should also consider a program offering paid master's degrees to qualified U.S. S&E students as an inducement to recruit these students for employment with the USG. The U.S. should continue upgrading K-12 education, increase incentives to attract American students to S&E disciplines to the doctorate level, amend regulations to ease immigration for qualified foreign scientists and engineers, and ease the hurdles foreign students face in immigrating or staying in the U.S.

D. OUTSOURCING/OFFSHORING. Corbett & Associates has said companies that anticipate waves of change will often rise with the tide; those that don't are normally crushed by these same waves. Outsourcing is one of those waves (Throckmorton, 2005). Outsourcing involves contracting out services (whether in the U.S. or not), and offshoring involves moving operations outside North America. Asia is a prime location for both, and with the rise of globalization, U.S. companies have increasingly moved work to lower-wage countries like India, China, the Philippines, Malaysia, Thailand and Vietnam (ACM Task Force, 2006).

According to a recent Global Insights study (2005) sponsored by the Information Technology Association of America, U.S. software and IT spending offshore totaled nearly $12.3 billion in 2004 and is expected to grow 20 percent annually through 2010 to nearly $38 billion (Global Insights). For example, China is expected to handle more than $1.7 billion in offshore work by 2008, supported by an estimated 400,000 IT professionals with wages as low as 25 cents per hour (Parr, 2006). While there are nearly 3.3 million IT workers (2.5 percent of total U.S. workforce), several recent studies have estimated the U.S. IT industry could lose (or never create) between 34,000 and 50,000 jobs annually (Global Insights).

On the other hand, Global Insight (2005) estimates offshoring may save the U.S. economy up to $10 billion in 2006, savings that will benefit consumers, companies and the economy overall. A decade of offshoring has already produced lower prices (by 0.8 percent across the economy), higher real GDP (to the tune of $147 billion) and higher real wages (12 cents an hour by 2010). Global Insight and ACM also concluded that offshoring has a positive, cumulative effect on job creation throughout the U.S. economy, with Global Insight finding an overall net gain of 257,000 new jobs (both IT and non-IT) created in 2005 and predicting 330,000 net new jobs in 2010 due to the economic benefits of offshoring. These new jobs help provide employment alternatives for those displaced by IT offshoring (Global Insights).

Another issue that must be considered with software offshoring is security and privacy, as employees of offshore companies may have access to sensitive customer and transaction data,

offering tremendous potential for corporate espionage, white-collar crime, privacy violations, identify theft and terrorism. While much of this relates to the back office aspects of offshoring, it is a real challenge for U.S. companies sending software and services work overseas. Recently proposed, as well as already enacted, legislation establishes (or seeks to establish) guidelines and standards for protecting this information (GAO, 2005), and it is essential that offshore companies have appropriate safeguards to ensure protection. This will be a growing area of concern, as no enforceable international law governs offshore centers (Ramanujan and Jane, 2006). Companies must develop procedures to ensure security and privacy and to identify and mitigate data protection risks. Increased IT outsourcing and strong congressional pressure for the Department of Defense to purchase commercial off-the shelf software carry similar risks. As recently as last September, key security provisions were added to the Federal Acquisition Regulations to require information security protections commensurate with security risks and to ensure IT security in all phases of the federal acquisition cycle.

Recommendations: Concern over outsourcing and offshoring is a natural reaction to companies seeking to reduce costs of doing business. To remain competitive, they must provide the best quality at the best price, and the USG cannot realistically undermine this cycle in the name of national security. Rather, the USG should collaborate with academia and industry to improve our educational system to produce more qualified IT professionals. The U.S. still has the best vocational and tertiary education system, but other countries are gaining ground in graduating engineers and scientists. The USG should not adopt policies that discourage companies from offshoring work, which increases overall productivity and enhances the U.S. economy overall. Government action should focus on ensuring data security and protection and assisting companies to establish sound retraining programs to assist displaced workers in transitioning into new employment. Companies should remain vigilant to the quality and security of their operations overseas, although market forces should drive this outcome.

E. INTELLECTUAL PROPERTY RIGHTS (IPR): One of the biggest challenges facing this industry is protecting and enforcing IPR. U.S. firms devote more money to R&D (and producing intellectual property) than any other country (and more than the rest of the G-7 combined) (OSTP, 2006); and other nations, corporations and individuals, including criminal organizations, use IPR violations to improve their economies, provide inexpensive or free products to consumers and to close the technological gap with the U.S.

In our global world, IDC estimates that businesses and consumers will spend over $300 billion on software over the next five years. Given the current state, IDC predicts that during that same five year period $200 billion worth of software will be pirated (BSA, IDC, May 2005). According to U.S. business groups, more than $200 billion in U.S. tax revenue is lost annually to counterfeiting and intellectual piracy (Zwaniecki, 2006). These statistics indicate why software piracy is a critical security issue in the IT industry.

The estimated 27 percent software piracy rate in the U.S. has a tremendous effect on our economy, resulting in estimated losses of over 25,000 jobs and $400 million in tax revenues (EVR SOFT). The Department of State and other USG agencies are working to protect IPR through the World Trade Organization (WTO) and its agreement on Trade Related Aspects of Intellectual Property Rights (TRIPS), as well as bilaterally. Unfortunately, critical regulations

and laws supporting TRIPS and commonplace in Western countries, such as patent law and data protection protocols, do not exist throughout the world.

Recommendations: While IPR violations will never reach zero, considerable USG effort remains. Diplomatic exchanges to improve education and enforcement of existing commitments and laws, and to obtain better legal regimes to protect IPR, must continue; and off-shoring companies must include IPR protection in their contracts. Patent and copyright reform must be addressed and streamlined as recommended by Mark Webbink's (2005) Federal Trade Commission report and the recommendations from the Justice Department's Intellectual Property Task Force (Ashcroft, 2004). Firms should also re-evaluate pricing schemes. If items are too expensive and easily transferable, the likelihood of IPR violations increases. Firms should include potential IPR problems in their pricing models to ensure a good balance.

F. Radio Frequency Spectrum: Enormous growth in spectrum-based technologies like wireless voice and data communications has significantly increased demands for spectrum from both private and public sectors. "Wireless" communications are an essential element of our national security and our society as a whole. As seen during recent disasters, this capability is vital to ensuring effective national and homeland defense, public safety and first-responder services. More importantly, spectrum is critical to the U.S. military's transformation efforts to a lighter, leaner and more mobile force to succeed in a network-centric battlefield (NTIA, 2006). In the end, spectrum management and allocation is essential for continued economic prosperity, homeland security and supporting our NSS.

Consequently, the demands for radio frequency spectrum are increasing at a rapid rate, despite the limits on available spectrum. The Federal Communication Commission (FCC) and the National Telecommunications and Information Administration (NTIA) have the responsibility for radio spectrum management. The NTIA has primary responsibility for managing spectrum policies for the USG and for advising on telecommunications issues. The FCC manages spectrum policy for all other users. To develop and implement a U.S. spectrum policy for the 21st century that meets the nation's security needs and supports economic growth, President Bush established the Spectrum Policy Initiative in June 2003. In March, 2006, the NTIA published its plan for implementing the President's initiative, titled Spectrum Management for the 21st Century. The plan focuses on improving stakeholder participation and qualifications, reducing international barriers to U.S. innovations in technologies, enhancing spectrum engineering and analytical tools to promote efficient and effective spectrum use and maximizing use of market-based economic mechanisms to incentivize efficient spectrum usage and management (NTIA, 2006b).

Recommendations: The NTIA's plan for implementing President Bush's Spectrum Policy Initiative is a step in the right direction in ensuring sufficient radio frequency spectrum is allocated to both the private and public sector. However, unless the telecommunications sector is held accountable for achieving these broad-reaching goals, the plan will not work. The USG, through the FCC and NTIA, must play an active role in managing the limited spectrum. Similarly, agencies across the government, notably DoD and DHS, must strive for efficient use of available frequencies. Ultimately, the government must strike a balance between frequency needed to ensure national security and that needed to support telecommunications progress and economic growth. In an interconnected world, the U.S. must work closely with international

telecommunications organizations and governments to foster efficient spectrum technologies and management.

G. Research and Development: U.S. IT R&D has been robust over the past 50 years. Spending has increased at an average annual rate of 4.8 percent and yielded remarkable products and services for consumers. The transistor, integrated circuits and World Wide Web all resulted from R&D investment in U.S. IT. These investments have fueled the economy and contributed to our security. However, the primary source of R&D funding has shifted from the federal government to private industry with a great deal more focus on development than on research. In the 1960s the USG made 65 percent of overall R&D investment whereas today it is only making about 25 percent (NSB, 2006).

IT claims a greater share of U.S. R&D investment than any other industry (running at 9 percent of domestic sales) (NSB, 2006), suggesting the industry is highly competitive and foresees continued growth, since most R&D investment is from the private sector. IT companies dominate worldwide R&D spending, with Microsoft, IBM, Sony, Nokia, Intel, Motorola, and Hewlett-Packard all appearing in 2003's top 20. While private sector R&D in IT is heavily focused on product development (where a return is expected in the near term), federal IT R&D dollars are going into basic and applied research, much of it at universities, where the payoff is longer term.

The IT industry today is focused on network convergence while the future holds promise for integrating RFID into other systems and the seemingly unlimited potential of nanotechnology. New products, services and processes resulting from R&D can enhance quality of life, continue to stimulate the economy and aid in maintaining national security. But realization of this promise will not happen without Federal government participation.

Recommendations: While experts anticipate current R&D funding trends will continue well into the future, the federal government must promote an environment that fosters innovation and investment by private industry focused more on basic research and less on development. Awards for innovation (like the recent X Prize won by SpaceShipOne) and tax credits for investment in innovation have been tried in the past (and remain popular with industry), but the competitive nature of IT's commercial applications means broad tax relief may no longer be appropriate in this industry. However, cyber security and cyber defense are areas where the government must be engaged, since the public good nature of these necessities suggests the private sector may be unwilling to invest sufficiently. In these cases, the USG must pick up the slack. Above all, government R&D investment planners must ensure enough basic research leading to long-term innovation.

H. Interoperability: Rapid advances in IT hardware, software and services across the technology spectrum present tremendous opportunities to enhance U.S. national security. However, the rapidly evolving IT ecosystem also presents vast challenges to the interoperability essential to our key national security capabilities. As the military moves towards network centric operations and a globally integrated grid, interoperability of systems and infrastructure is essential. An increasingly complex and fluid joint and combined battlefield needs a seamless communications and systems interface to maximize our fullest national power. Contrary to

earlier forays into government-initiated standards (e.g. ADA programming language in the early 1990s), the government has allowed industry to take the lead in establishing the key standards essential for interoperability, as it should.

Recommendations: The government must remain engaged in industry efforts such as the Network Centric Operations Industry Consortium, in order to remain informed and to guide industry efforts to establish and maintain standards needed for interoperability. These efforts are targeted on integrating a common global framework and enterprise architecture at domestic and international levels.

CONCLUSION: Over the last three months, this seminar engaged in extensive research, comparative market analysis and discussions with industry leaders, private firms, organizations and governments to assess the ability of the IT industry to support our nation's national security objectives. IT, as we learned, is a very complex, global and ubiquitous entity that is not only an industry, but a foundational framework for all other industries and activities. IT is the bedrock of globalization and the key enabler of economic growth in the United States over the last 20 years.

The seminar engaged in detailed studies of five companies representing significant segments of the industry. Although companies achieved varying degrees of commercial success, the represented segments were in good health overall and most analysts/experts projected continued success and growth. While the industry is healthy, the level and pervasiveness of technological change will increase considerably across the spectrum. Data convergence, combined with extraordinary advances in hardware, software and e-solution capabilities will continue to offer more and more opportunities for productivity enhancements. These opportunities notwithstanding, the industry has a few challenges to address to remain the world-leader in IT innovation, capabilities and services.

First and foremost is protecting our information-based capabilities. As the use of these technologies becomes routine, corporations and even our military become increasingly vulnerable to adversaries willing to exploit our reliance on IT for personal or national gain. The USG, in partnership with academia and industry, must develop, execute and validate an overall plan to protect our critical (information) infrastructures. Secondly, we must protect our valued intellectual property and human capital. We note a lack of qualified S&E graduates in some areas, though widespread shortages of qualified engineers and job losses to off-shoring seem to be misrepresented. Yet we can't be complacent. The U.S. has a significant advantage in the innovative ecosystem, and we must ensure appropriate levels of basic research and qualified personnel to maintain our advantage.

Based on this exhaustive examination, we believe the IT industry is well-positioned to support our national security. However, complacency in this dynamic environment can quickly disrupt and challenge our position, putting the U.S. at a disadvantage. The IT industry is performing well now, and modest regulation seems most likely to support its strengths in innovation. The key is for the USG to re-evaluate the numerous legislative markers, eliminate unnecessary regulation, and refrain from anticipatory legislation as it addresses the challenges highlighted throughout this paper…a very tall task. Success will require a firm commitment from, and collaboration among, government leaders, industry and academia.

ANNEX A

Information Technology – Defining the Industry
North American Industry Classification System (NAICS)
2002 Economic Census Industry Series

NAICS	Segments of the Information Technology Industry
334111	Electronic Computer Manufacturing (Apple)
334112	Computer Storage Device Manufacturing
334113	Computer Terminal Manufacturing
334119	Other Computer Peripheral Equipment Manufacturing (Cisco)
334220	Radio and Television Broadcasting and Wireless Communications Equip. Mfg. (Nortel)
334290	Other Communications Equipment Manufacturing
334310	Audio and Video Equipment Manufacturing
334412	Bare Printed Circuit Board Manufacturing
334413	Semiconductor and Related Device Manufacturing
334418	Printed Circuit Assembly (Electronic Assembly) Mfg
334611	Software Reproducing
334613	Magnetic and Optical Recording Media Manufacturing
5112	Software Publishers (Oracle)
51419	On-Line Information Services
5142	Data Processing Services
516	Internet Publishing and Broadcasting
517	Telecommunications (Verizon)
518	Internet Service Providers, Web Search Portals, and Data Processing Services
5415	Computer Systems Design and Related Services

NAICS and Firms selected for in-depth analysis as industry segment proxies

As this table suggests, assembling inclusive data with which to analyze the wide ranging information technology industry is no easy task, with elements of the industry scattered throughout the economy's manufacturing and services sectors. The task is complicated by changes in the NAICS from 1997 to 2002, and by the use of other systems for industrial classification (i.e., the Standard Industrial Classification used by the Securities and Exchange Commission) and reporting trade data (i.e., the Harmonized Tariff System used by the U.S. International Trade Administration and other trade-focused organizations). Regardless of its cumbersome nature, the Department of Commerce's Bureau of Economic Analysis (BEA) regards NAICS as superior to SIC in allowing a more accurate depiction of the performance of the services sector. BEA is engaged in reconstructing estimates of industrial output based on NAICS (Yuskavage and Fahim-Nader, p. 70-1). Unfortunately, a comprehensive analysis of IT – indeed of any industry – in today's global economy also necessitates careful examination of trade data, which are most often presented under the Harmonized Tariff System that is not compatible with NAICS.

ANNEX B – DOMESTIC FIELD STUDY TRAVEL

During the week of April 17-21, the IT seminar traveled to Silicon Valley (San Jose), CA, to discuss IT issues with company and industry leaders. We've highlighted the key issues.

While the companies we visited represent different sectors of the market, they had key concerns in common. The first issue dealt with the workforce and the number of qualified IT personnel. The concern varied from little to significant that companies could find enough engineers and scientists with the right expertise. The Silicon Valley Association has discussed this issue on multiple occasions, but hasn't identified key concerns or recommendations. Companies generally felt USG policy intervention was late and misdirected. The Sarbanes-Oxley legislation being just the latest regulatory requirement that is costing companies much more than originally anticipated. Most favored government subsidies and tax breaks on R&D, but weren't relying on this support. One way or another, they need to maintain high levels of R&D spending to remain competitive in this market. Another concern affecting most companies is supplier reliance. We heard that 99 percent of the computer power supplies are produced in China and that it would take nearly 12 months to setup a fabrication line in the U.S. While most companies have alternate suppliers, this could turn into a strategic computing shortfall if relations with China deteriorate. This is just one of many examples where companies have to specifically identify multiple suppliers to ensure un-interrupted support during times of political, economic or environmental disruptions. Specific company discussions follow:

ORACLE CORPORATION (18 Apr): Oracle discussed their Enterprise Resource Planning (ERP) system, which provides decade-long support for company resource requirements. Oracle's main competitor is the German database company SAP; both have enjoyed success in winning DoD projects.

Oracle's goal is to be number one in every market it enters, which determines its strategies on market entry and acquisitions. Oracle has acquired numerous companies over the last three years, and they've focused a lot of energy on the company culture and assimilating acquired company personnel, processes and procedures into the Oracle environment.

A final briefing highlighted Oracle's commitment to database security as a differentiator in the database market. Oracle is constantly improving security to eliminate vulnerabilities and counter increasingly sophisticated attacks trying to access critical business and personal information.

SUN MICROSYSTEMS (April 18): Sun is a trendsetter in applying IT solutions internally. They've transformed from a standard distributed desktop to a thin client environment under their "Sun IT Vision". Each Sun employee carries a personal identification card similar to DoD's Common Access Card (CAC) which enables them to log onto any Sun Microsystems computer and gain access to all their business and personal files (roaming profile). Sun has realized significant savings in on-site support personnel, security incidents, patch management costs and most importantly, power consumption requirements. The thin client computer uses 28 watts of power as compared to a standard desktop computer's 150 watts.

They also discussed their concepts for Software as a Service (SaaS), Service Oriented Architectures (SOA) and grid computing. These items are discussed in the trends section of the main paper. Sun is a proponent of Open Source Standards and recommends Congress engage to force open standards on the market.

APPLE COMPUTERS, INC. (April 19): Apple employs around 14,500 personnel and is one of the few IT companies that didn't express concern with attracting domestic science and technology talent. They are a global company with U.S. domestic sales comprising 55 percent of total sales. All Apple R&D is performed within the United States.

Apple staff demonstrated their Mac OS 10 operating system. The Mac OS 10 operating system is processor independent, Unix based, and open source. Apple has a saying, "Standards Based, Mac Better". Their key themes focused on making the user experience important and making things easier. They highlighted Apple's many innovations to the computing industry: the first to use USB and the first company with an attached laptop keyboard to name a few.

Even with all these innovations, Apple's largest revenue source is iPod sales. Overall, Apple sold 42 million iPod units, 76 percent in 2005. Also last year, their iTunes division garnered over $4.5 billion in revenue. This is an increase of nearly 248 percent from 2004 and represents nearly 33 percent of overall revenues.

SEMI-CONDUCTOR INDUSTRY ASSOCIATION (SIA) (April 19): SIA is lobbying for more government financial support for R&D, improvements in U.S. math and science education, assured access to a highly-educated foreign workforce, and a "level playing field" for R&D and manufacturing the U.S.

The SIA briefing indicated the U.S. leads the world in semiconductor market share, but other countries (Europe, Korea, Taiwan) are making impressive gains and China has captured 20 percent of the worldwide integrated circuit (IC) market. The U.S. industry share of total semiconductor manufacturing has declined. SIA suggested this foreign shift may be a national security threat.

One reason for this decline is that it costs nearly $1 billion more to build and operate a fabrication plant in the U.S. than overseas. This is due to tax treatment, capital grants and other local factors like utilities, labor and logistics.

The briefing also highlighted that U.S. nationals comprise 90 percent of new bachelor's in electrical engineering graduates but that foreign nationals lead in master's (54 percent) and Ph.D. (65 percent) degrees.

BROCADE, INC. (April 20): Brocade is a ten-year-old company that focuses on the 20 percent niche storage markets the "big companies" can't satisfy with their standard products. They supply large data storage and support capabilities **(Look at Brocade notes).**

While discussing government regulation and legislation, Brocade claimed there are over 8,000 regulations that govern IT within other industries and the actual IT industry. While

compliance with the Sarbannes-Oxley Act costs companies considerably more than anticipated, Brocade has benefited because companies must now electronically store their documents and communications. Another example of restrictive regulation is the European Union's Removal of Hazardous Substances Act (ROHS) to which Brocade must adhere to in order to do business in Europe.

Factoids of interest: in 1995 terabyte warehouses with 1,000 gigabyte drives were standard. Today, data storage is measured in exabytes (10^{18}). Fifteen years ago 90 percent of data transfer was done by analog means. Today, 92 percent of data transfer is by digital means. Finally, nearly 36 billion emails are created daily.

Brocade does most of their manufacturing in China, although most final assembly and configuration is done in the U.S. The fabrication facility, owned and managed by the Taiwanese firm Foxconn, employs nearly 140,000 personnel and is located in Shenzhen, China. The 10-30 percent costs savings Brocade achieves through oursourcing its manufacturing allows the company to remain competitive.

SILICON GRAPHICS INC. (21 April): Silicon Graphics Incorporated (SGI) employs about 1,800 people, has operations in over 50 countries, and has annual revenues of over $700 million. SGI suffered from the dot-com bust of 2000, as did other Silicon Valley companies, and is restructuring. IBM and Cray Supercomputers are SGI's biggest competitors. SGI is moving away from it previous graphics competencies and focusing on the high performance computing environment to help streamline focus and operations. (SGI filed for Chapter 11 bankruptcy protection on May 8.)

ANNEX C – INTERNATIONAL TRAVEL

From May 4-20, the IT seminar traveled to Beijing, Bangkok, Singapore and Tokyo to discuss IT issues with country, company and industry leaders. Although there were many differences, some key concepts transcended country boundaries. First and foremost these countries valued relationships. To be successful, corporations had to understand cultural differences and develop relationships with key country and company leaders; otherwise, they encountered difficulty in consummating deals. The next commonality dealt with the business language. We heard in many discussions that "English is the international IT language" and those countries that moved toward this concept were more successful than those who didn't. A final key concept dealt with the IT value chain. Most of the Asian countries fall well below the U.S. in knowledge and innovation. They are focused on the back-end and low cost operations like manufacturing and coding. Some are moving up to the design and integration, but are still trying to break through. Although Japan and Singapore are making great strides, they are still years away from competing with the U.S. in innovation. However, they have shown to be great adopters of U.S. technologies and ideas. Following is a brief synopsis of each country visit:

Beijing – The seminar met with U.S. Embassy staff to review Chinese political and economic issues, particularly as they impact the IT industry. Among the key concerns were the continuing huge trade deficit, which appears on track to match 2005's record, China's undervalued currency (although the value of the *yuan* has recently appreciated), growing political unrest, overcapacity in a number of industries, and the rising proportion of non-performing loans. They characterized Chinese president Hu Jin Tao's recent visit to the United States as substantively successful, and noted China's rising – and substantial – budget in support of R&D, including in the IT industry.

Representatives of private sector IT interests discussed many of the same issues but focused heavily on Chinese education. While China's educational institutions are producing greater numbers of S&E degrees, tertiary education in the U.S. is still providing graduates with better problem-solving skills and experience. As a result, U.S. graduates are preferred, and private sector observers judge that China's capacity to "innovate" remains constricted.

At the same time, IT in China is growing rapidly. The sector overall is growing at 25 percent per annum, and the software and services market is growing at 50 percent annually. This growth is building on an already impressive base: China is the #1 factor in Asian IT growth, the world's #2 PC market, #2 in Internet subscribers, and the world's largest telephone (particularly wireless) market. China, of course, faces significant IT challenges. India is far ahead in outsourcing and IT services. China lacks IT leadership and sufficient qualified technical personnel, legitimate software must contend with a 90 percent (by some accounts) piracy rate, and weak "rule of law." A more generic lack of legal and regulatory infrastructure and multiple levels of government with often competing interests complicate business and innovation prospects.

Nonetheless, China aims to continue moving up the technology ladder towards building an information economy, and foreign investors in China's IT sector are likely to continue playing a major role, even as Chinese firms enjoy increased revenues.

Bangkok – Meetings with members of the American Chamber of Commerce's ICT Committee provided the seminar with an extensive overview of Thailand's current IT baseline, directions for future development, and the role and prospects of U.S. IT firms in the Thai IT sector. All major U.S. and foreign IT firms are represented in Thailand across the spectrum of IT industries from manufacturing to software development and services. Thailand's overall domestic IT market now stands at over $3 billion and is increasing at roughly 20 percent annually. About half of the spending is for hardware, and about half of the spending is by enterprises. Government spending accounts for around 20 percent of IT spending. Key leaders expect continued IT spending growth in banking and finance, telecommunications (though growth is slowing), manufacturing, retail, and logistics sectors. Thailand has plenty of room for continued growth in personal computing, as penetration rates for computers and internet usage remain relatively low and vary widely across the country. In Bangkok, for example, 28 percent of households had computers in 2004 as opposed to just 6 percent of households in the poorest northeastern section of Thailand. The availability of telephone service is much higher; with 44.5 percent of the population (heavily overweight in Bangkok) having fixed line service, and 36 percent of the population has access to mobile phones (NECTEC, 2005).

The Thai government plays a significant role beyond buying 20 percent of IT products and services sold in Thailand, and some major elements of its broad "e-government" initiative have been notable failures (such as the "smart" national ID card). On the promotion side, the government is actively seeking to attract IT companies to locate in Thailand with a variety of tax and financial incentives – Thailand now has some 4,000 IT companies – and institutionally has set up a Software Park (as an incubator), Science Park, and the National Science and Technology Development Agency, including the National Electronics and Computer Technology Center. A significant gap remains in legislation to enable the uptake of e-commerce, and inadequate institutional arrangements in the telecommunications sector are slowing the adoption of the latest technologies.

Like China, Thailand must deal with a lack of skilled IT personnel and inadequate English language capability, and is attempting to address these through training and certification, more resources for higher education, and allowing companies to bring in highly skilled personnel (in some cases). Still, the shortages are significant and require more focused government and market-based efforts if they are to be bridged.

Singapore – Singapore presents a stark contrast with China and Thailand on a number of fronts, not the least of which are the level of economic development and IT penetration and savvy. Maintaining its first-in-the-world standing in IT is a major preoccupation of the Singapore government, particularly the Infocomm Development Agency (IDA). Over 50 percent of houses in Singapore already have access to broadband, but IDA is developing plans to extend wired broadband service to virtually the whole island and to significantly upgrade wireless Internet service. On the telecommunications front, Singapore is among the world leaders: mobile telephone penetration in Singapore exceeds 100 percent.

With a per capita GDP of $26,000, Singapore is no longer competitive in IT manufacturing strictly in terms of labor costs. High end manufacturing (for example 300mm semi-conductor wafers) benefits from very highly qualified Singaporeans and skilled labor

imported largely from Malaysia. English language skills are universal in Singapore, and a liberal trade regime and government incentives make manufacturing and investment attractive. Singapore also benefits from its location, political stability, and ability to interpret Asian economies to the West and Western economies to Asia. As a result, Singapore is home to offices of nearly 1,500 American companies (in all industries) and nearly 7,000 multi-national corporations, including all major global IT players.

Tokyo – Japan matches up more closely to the U.S. than any other Asian country and is now operating under its third five-year S&T plan. The plan projects government expenditures of $225-250 billion through 2010 focusing on nanotechnology, IT, environmental technologies, and biotechnologies; and emphasizing collaboration among industry, academia, and the government. The plan also emphasizes competition among research institutions for funding and hopes to see around 30 institutions "break away from the pack." Japan's government is very concerned that China may overtake Japan in the IT sphere and has identified IT as a national development priority. Although China is presently far behind Japan in almost every measure, the government's concern is not entirely misplaced. While Japan is the Asian leader in innovation and remains ahead of the pack in commercializing new technologies, it is not considered an "innovative society" globally. In fact, some observers believe the Japanese educational system is weak in preparing qualified engineering and science graduates, and flash memory may be the only IT segment where Japanese companies retain a competitive edge globally.

While the Japanese government is supporting IT through its third five-year S&T plan, observers believe the government's wisest course of action should be to limit policy intervention. (Reforming tertiary education should be accomplished, however.) They believe that Japan stands to widen its IT lead over China and India (both of which see strong government roles in promoting IT) as long as government intervention remains light.

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